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EXPERIMENTAL DETERMINATION OF OPTIMUM REFRIGERANT INSULATION COMBINATION IN A VCR SYSTEM USING TAGUCHI METHOD

ANUSHA PEYYALA[1] & NVVS SUDHEER[2]

[1]*Department of Mechanical Engineering, V P Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India*

[2]*Department of Mechanical Engineering, R V R & J C College of Engineering, Guntur, Andhra Pradesh, India*

ABSTRACT

Various studies have been done to investigate the effect of various parameters on the performance of the vapour compression system. In the vapour compression refrigeration cycle, external parameters such as refrigerants and Insulation materials have a higher effect on the performance of vapor compression refrigeration system. For the purpose of finding the best combination, we have selected the Taguchi method. Minitab software helped us to apply the Taguchi method to find out the possible combinations that are formed. In the present study, Using Taguchi L16 orthogonal array considering the two deign parameters viz. Type of Refrigerant and Type of Insulation experiments were conducted and were analyzed. Analysis of variance (ANOVA) was carried out to obtain the significant values of the Coefficient of performance and Work required for the compressor at 95 % confidence level. From ANOVA it can be concluded that the Insulation (X) and Refrigerant (Y) both are significant for COP and Wc. Percentage contribution of input parameters was also calculated. For COP experiment the percentage contribution of Insulation (X) is equal to 95.85% and Refrigerant (Y) is equal to 3.87%. For Wc experiment, the percentage contribution of Insulation (X) is equal to 77.58% and Refrigerant (Y) is equal to 19.46%.

KEYWORDS: ANOVA, COP, Insulation, Refrigerant, Taguchi & VCRS

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Original Article

1. INTRODUCTION

As we know, Refrigeration is the science of producing and maintaining temperatures below that of the surrounding atmosphere. The performance of a system is depended on so many factors out of the two main factors are working substance refrigerants and the insulations of gas and liquid pipelines in a VCR system. So many authors have worked on this area of interest like in 2005, Ahmet Z. Sahin, et al [1], explained regarding Optimum insulation thickness of a circular duct subjected to external radiative heat transfer for a given quantity of insulation material. A circular duct through that fluid is transported from one finish to the opposites taken into account. The thickness of the insulation is assumed to be linearly variable since this is often straight forward to implement in observe. Thus, the slope of the insulation thickness is taken into account because of the parameter for optimum insulation. Variations of the majority temperature of the fluid furthermore because the temperature of the outer surface of the insulation area unit evaluated.

In 2005, Ahmet Z. Sahin, Muammer Kalyon et al [2], obtained an analytical solution for the insulation thickness variation over a pipe to take care of identical outer surface temperature. A heated fluid is taken into account to be flowing through the pipe. The number of insulation material is assumed to be restricted. Heat transfer from the outer surface of the pipe is thru convection and radiation. The solution of the insulation thickness is found to be freelance from the outer surface convective and radiative heat transfer coefficients. In 2010, Alireza Bahadori, Hari B. Vuthaluru et al [3], explained about the selection and determination of the optimum thickness of the insulation. In this study, a simple method is developed to estimate the thickness of thermal insulation required to arrive at the desired heat flow or surface temperature for flat surfaces, ducts, and pipes. The proposed correlation calculates the thermal thickness up to 250 mm for flat surfaces and estimates the thermal thickness for ducts and pipes with outside diameters up to 2400 mm. In 2012, Ali Kecebas et al [4], explained that using insulation materials the energy consumptions in buildings can be reduced considerably. In his study, insulation thickness has been optimized by victimization exergy methodology and life-cycle value idea for the case of victimization numerous fuels like coal, gas, and fuel–oil. The optimum insulation thickness decreases with the increasing of the inlet temperature of the fuel, and with the decreasing of excess air coefficient, temperatures of stack gases and combustion chamber. In 2013, Y. H. Yau H. L. Pean et al [5], studied concerning the impact of weather variation on a split Air Cooled Ducted Blower (ADB) air conditioner in an office building located in malaysia. In their study, the influence of weather variation on the performance of the ADB air conditioning (AC) systems in terms of total cooling capability and sensible Heat factor (SHF) are studied.

In 2015, Abdullah Yildiz, Mustafa Ali Ersoz et al [6], the study deals with the investigation of optimum insulation thickness of VRF (variable refrigerant flow) systems. Optimum insulation thickness, energy savings over a time period of ten years and payback periods are determined for high-pressure gas pipelines, low -pressure gas pipelines and low-pressure liquid pipelines beneath the heating-only and cooling-only modes of the three-pipe VRF system using R-410A as the refrigerant. undercooling mode of the VRF system, the optimum insulation thickness varies between seven and eight millimeter for pipe sections of flow pressure gas pipeline and low-pressure liquid pipeline. In 2016, Mustafa Ali Ersoz, Abdullah Yildiz et al [7], performed investigations of optimum insulation thickness, price savings and payback periods for gas pipeline and liquid pipeline under the heating operation of 1500 hours and cooling operation of 1500 hours of a split air conditioning system that used flexible insulation foam as insulation material. Analyses are performed for four totally different refrigerants indicated as R-22, R-134a, R-407C, and R-410A. The results indicate that under heating mode, the optimum insulation thickness of gas pipeline varies from nine to twelve-millimetre counting on the analyzed refrigerants, whereas the optimum insulation thickness of liquid pipeline varies from half dozen to nine millimeter looking on the analyzed refrigerants. Once it involves cooling mode, whereas optimum insulation thickness of gas pipelines is nine millimeter for all the analyzed refrigerants, optimum insulation thickness of liquid pipelines is half dozen millimeter for all the analyzed refrigerants. under the given operation conditions, R-407C shows the best potential for price savings through the optimization of insulation thickness, since it's the lowest mass flow rate. In 1999, C. Aprea, F. de Rossib, A. Greco et al [8], in their work the mean heat transfer coefficients of R22 and R407C in the twenty millimeter ID coaxal counter flow evaporator of refrigerating vapor compression plant are by experimentation measured. The results illustrate that the R22 heat transfer coefficient is usually bigger than that of R407C. it's been discovered that the heat transfer coefficient of R22 is usually higher than that of R407C. The distinction decreases from fifty four to twenty four percent with increasing the refrigerant mass flux. In 2001, S. G. Kim, M. S. Kim, S. T. Ro et al [9], presented test results and developed a dimensionless correlation on the idea of the experimental information of adiabatic capillary tubes for R22 and its

alternatives, R407C and R410A. a new correlation based on Buckingham theorem to predict the mass flow rate through the capillary tubes was given based on in-depth experimental information.

In 2004, Mark W. Spatz, Samuel F. Yana Motta et al [10], This paper targeted on analysis of the R-22 replacement choices for medium-temperature refrigeration applications which incorporates a thermodynamic analysis, comparison of heat transfer and pressure drop characteristics, system performance comparisons using a valid elaborated system model, issues of safety, and determination of the environmental impact of refrigerant choice. 3 potential alternatives to the R-22 were studied 404A and R-410A and R-290. R-410A is shown to be an efficient and environmentally acceptable choice to replace R-22 in medium temperature applications. R410A was shown to be an efficient refrigerant due to its thermal properties leading to improved heat transfer and pressure drop characteristics. In 2005, Man-Hoe Kim, Joeng-Seob Shin et al [11], did an experimental investigation of evaporating heat transfer in 9.52 mm O. D. horizontal copper tubes. The refrigerants tested were R22 and the near-azeotropic mixture, R410A. At the same test conditions, the evaporating heat transfer coefficients for R410A were 97–129% higher than that of R22. In 2012, R. Llopis, E. Torrella, R. Cabello, D. Sa´nchez et al [12], In their communication the main energy parameters, such as cooling capacity and COP are analyzed and discussed. Substitution of R22 with chlorine-free refrigerants has been analyzed from an energy point of view. The selected substitutes were drop-in fluids for low-temperature applications, R422A and R417B, and one retrofit refrigerant, R404A. The four fluids were tested in the same test plant, which was designed for operation with R22. In 2012, J. H. Wu, L. D. Yang, J. Hou et al [13], in their work, an original R22 wall room air conditioner with a cooling capacity of 2.4 kW and energy efficiency ratio (EER) of 3.2 is retrofitted with a compressor of a 20% larger displacement to charge R290 and R1270 for performance experiments. In 2015, Gang Yan, Chengfeng Cui, Jianlin Yu et al [14], in their paper authors proposed a modified vapor-compression refrigeration cycle (MVRC) system operating with the zeotropic mixture R290/R600A for domestic refrigerator-freezers. In the MVRC system, a phase separator is introduced to enhance the overall system performance. In 2015, Qiqi Tian, Dehua Cai, Liang Ren, Weier Tang, Yuanfei Xie, Guogeng He, Feng Liu et al [15], in their paper, the refrigerant mixture R32/R290 is investigated as the drop-in replacement for R410A in household air conditioners. The GWP of it is only 22% of that of R410A. Experimental results show that the refrigerant charge amount of R32/R290 is reduced by 30.0% to 35.0%; the cooling and heating capacities are increased by 14.0% to 23.7%. In 2015, Vedat Oruc, Atilla G. Devecioglu, Ugur Berk, Ibrahim Vural et al [16], In this paper, the amount of consumed energy, cooling capacity and COP values of R417A, R422A, R422D and R424A, which can be used as alternatives to R22, were determined experimentally for a split type air conditioning device at the ambient temperatures of 35, 38 and 41 °C. It was noted that the most suitable refrigerating fluid was R424A, which can be used instead of R22 since the COP of R424A was smaller than that of R22 by 2.5% only at an ambient temperature of 41 °C.

In 2016, Zhaogang Qi et al [17], in their paper compared the heat rejection and pressure drop characteristics for heat exchangers using R22, R410A, and R407C as working fluids. In 2000, A. Cavallini, G. Censi, D. Del Col, L. Doretti, G. A. Longo, L. Rossetto et al [17], in their work presented reports on experimental heat transfer coefficients and pressure drops measured during condensation inside a smooth tube when operating with pure HFC refrigerants (R134a, R125, R236a, R32) and the nearly azeotropic HFC refrigerant blend R410A. In 2002, M. Goto, N. Inoue, R. Yonemoto et al [18], in their paper heat transfer coefficients were measured for the condensation of R410A and R22 inside internally grooved horizontal tubes. The experiment was performed for five different kinds of internally grooved tubes of about 8.00 mm outside diameter. In 2004, Yongchan Kima, Vance Payneb, Jongmin Choice, Piotr Domanski et al [19], in their paper an empirical correlation was developed from a power law form of dimensionless parameters generated by the Buckingham Pi

theorem. In 2005, S. Wellsandt, L. Vamling et al [20], paper presented an experimental investigation of in-tube evaporation of R410A and R407C for a 4 m long herringbone microfin tube with an outer diameter of 9.53 mm. In 2012, Xing Xu, Yunho Hwang, Reinhard Radermacher et al [21], explained that the potential substitute for R410A is R32, which has a GWP of 675. This paper investigates the performance difference using R410A and R32 in a vapor-injected heat pump system. In 2015, Marco Bortolini, Mauro Gamberi, Rita Gamberini, Alessandro Graziani, Francesco Lolli, Alberto Regattieri et al [22] explained an experimental analysis about the retrofitting of two commercial stationary refrigeration systems to investigate the performances of HFC R410A and R407f, chosen as effective alternatives to HFC R404A. Results indicate the R410A is a potential alternative for the system even if R407F also represents a suitable solution. In 2015, Abdullah Alabdulkarem, Radia Eldeeb, Yunho Hwang, Vikrant Aute, Reinhard Radermacher et al [23], explained regarding the environmental impact of high warming potential (GWP) refrigerants pushed the HVAC&R industry to research various refrigerants. R410A could be a common refrigerant for air conditioning and heat pumping applications however contain a GWP of 2,088. In 2009, M. S. Phadke [24] explained that Taguchi methodology of the style of experiments is one among the vital tool used for design to produce top quality product quickly and at the low price.

Taguchi methodology relies on performing analysis or experiments to check the sensitivity of a collection of response variables to a collection of control parameters by considering experiments in “orthogonal array” with an aim to achieve the optimum setting of the control parameters. Orthogonal arrays offer the best set of well balanced (minimum) experiments [25]. The S/N ratios, that are log functions of the desired output, serve as the target functions for optimization, facilitate in information analysis and also the prediction of the optimum results. There are 3 kinds of S/N ratio that are of common interest for the optimization of static problems. 1. Smaller-the-better, 2. Larger-the-better, and 3. Nominalthe-best. various factors have an effect on the strength to a special degree. a better feel for the relative effect of the various factors is obtained by the decomposition of variance, which is often known as an analysis of variance. The main objective of this work is to determine the optimum refrigerant insulation combination to be used for a VCR System. The impact of the various insulations on COP and compressor work input required was investigated. Taguchi technique of analysis is employed to reduce total number of experiments. The experimental data is analyzed using Taguchi technique for optimum conditions of input parameters. ANOVA is distributed on experimental data to seek out the numerous effect of the input parameters.

2. EXPERIMENTAL

2.1 Insulations & Refrigerants

Out of so many systems we have selected vapor compression refrigeration system (VCRS) which has the highest COP than any other system in the field of HVAC. The important environmental and safety properties are Ozone Depletion Potential (ODP), Global Warming Potential (GWP), Total Equivalent Warming Index (TEWI). According to the Montreal protocol, the ODP of refrigerants should be zero, i. e., they should be non-ozone depleting substances. Refrigerants having non-zero ODP have either already been phased-out (e. g. R 11, R 12) or will be phased-out in near-future (e. g. R22). Since ODP depends principally on the presence of chlorine or bromine within the molecules, refrigerants having either chlorine or bromine cannot be used underneath the new rules. GWP Refrigerants ought to have low GWP worth to reduce the problem of global warming. Refrigerants with zero ODP but a high value of GWP (e. g. R134a) are probably to be regulated in the future. The factor TEWI considers both direct (due to release into the atmosphere) and indirect (through energy consumption) contributions of refrigerants to global warming. In this study 5.25 KW SAC system was

fabricated to test the performance of a VCRS using R22 and R410 an as refrigerants. From literature, we understood that the type of Gas and liquid pipelines insulations are also affecting the COP other than working substance refrigerants. Next, we identified all the possible insulations available in the market both using mostly used and unused ones. Insulation Materials Chosen for Experimentation are EPF, NRF, PFS, NYR, NRF+AF, NRF+NYR, PFS+NYR. The radius of insulation that should be wrapped around the pipelines is also calculated using the principles of Critical radius of Insulation for Cylinders concept.

2.2 Experimental Methodology

Experimentation is done on the SAC system of 5.25 KW designed for R22 was selected for performance evaluation. It was tested as per the Indian Standard 1391 (1992) Part I, for unitary air conditioners.

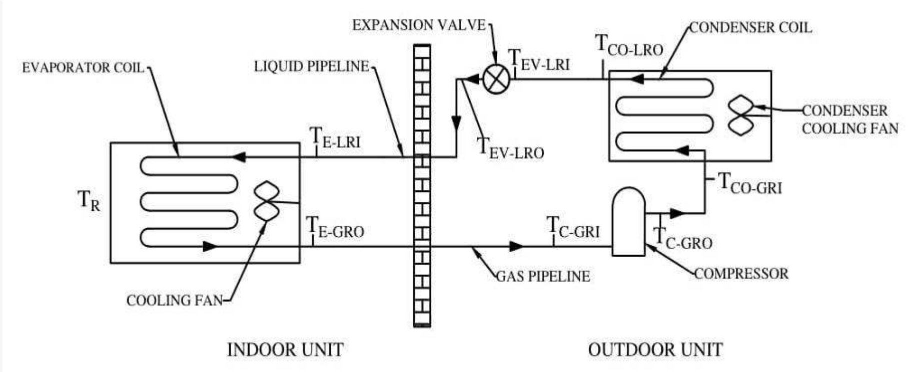

Figure 1

The performance of the SAC system using R22 and R410a were compared considering the selected insulation materials. During this experimentation, temperatures at various points were taken by using thermocouples until steady state is achieved.

2.3 Design of Experiments by Taguchi Method

The design of experiments was done with Taguchi's L16 orthogonal array. The L16 orthogonal array contains sixteen rows and 2 columns, with eleven degrees of freedom (df) to treat one parameter with Eight levels and another parameter with 2 levels. Each parameter level is about in line with the L16 orthogonal array, supported Taguchi methodology of style. The experimental results are further transferred into the S/N ratio victimization MINITAB 17 software package. The different levels of variables utilized in the experiment are listed in table 1.

Table 1: Levels of Variables (Control Factors) used in Experiment

Levels								
Control factors	1	2	3	4	5	6	7	8
Insulations (X)	I1	I2	I3	I4	I5	I6	I7	I8
Refrigerents (Y)	R22	R410A						

When the response is to be Larger-the-better [maximized], Taguchi uses the following formula for S/N ratio (η).

$$\eta = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{y_i^2}\right)\right) \tag{1}$$

When the response is to be smaller-the-better [minimized], Taguchi uses the following formula for S/N ratio (η).

$$\eta = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\left(y_i^2\right)\right) \tag{2}$$

Next, the experimental results are statically studied by analysis of variance (ANOVA).

3. RESULTS & DISCUSSIONS

3.1 Experimental Results

The experimentation is performed using the Taguchi orthogonal array Technique L_{16}. The study investigated the performance of VCR System using chlorodifluoromethane and a blend of difluoromethane & pentafluoroethane as the working fluids. Two factors were examined like COP of the fabricated VCRS and the Work input required for the compressor, Wc using different considered insulations. For each refrigerant insulation combination, 5 times readings have taken to achieve the repeatability in results.

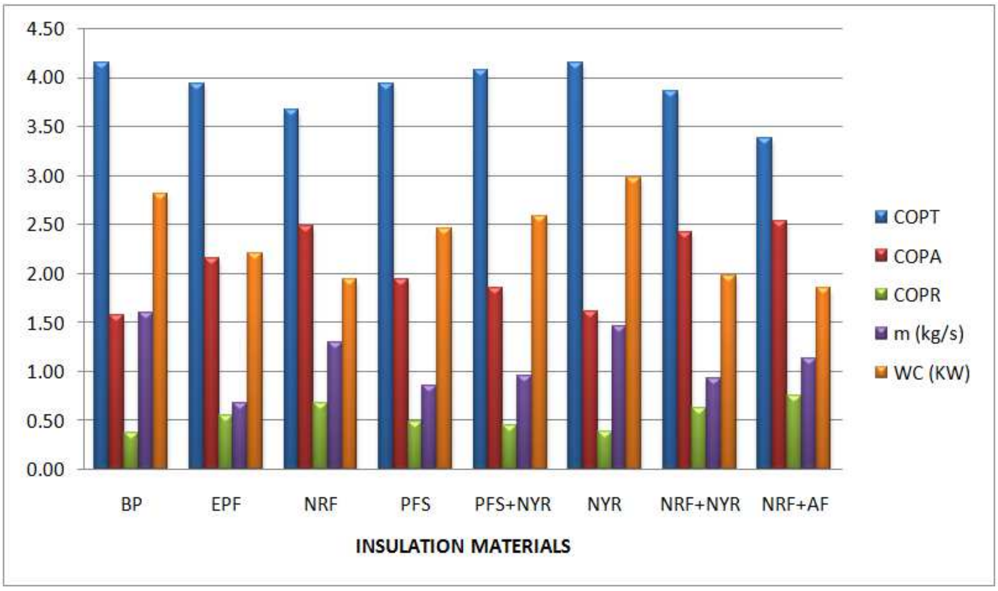

Figure 2(a): Various Values Calculated for SAC for Various Insulation Materials while using R22

Temperature values were taken at various considered locations with the help of thermocouples until steady state is achieved and the remaining thermo physical properties were taken from REFPROP9[26]. The variations of COP and Wc were shown in the figure 2.(a),(b) respectively.

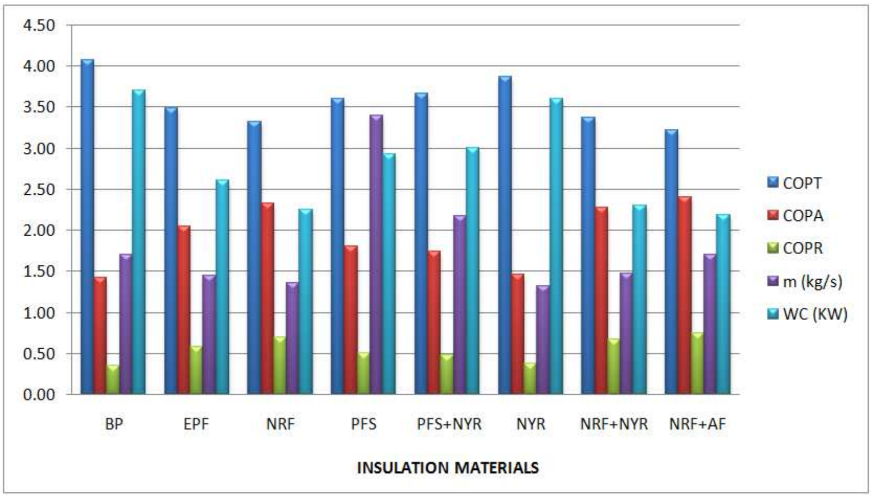

Figure 2(b): Various Values Calculated for SAC for Various Insulation Materials While using R410a

Various values like COPT, COPA, COPR, mass flow rate and Wc were calculated from the obtained data but mainly focussed on COPA and Wc for further study in this work. From experimentation, it is observed that COP_A for NRF+AF gives the highest value for R22 and COP_A value increases from 2% to 61% while using insulation materials of various types. Power required while using insulation materials is less when compared to Bare Pipe except for NYR since, W_C is reduced by 33.84% to 7.93% while using various insulation materials and W_C reduced maximum while using NRF+AF and while using NYR, W_C increased by 5.85. It has been observed that COP_A is high while using NRF+AF for SAC with R410a and COP_A value increases from 2.7% to 69% while using various types of insulation materials. Also, the power required for SAC is less while using NRF+AF for R410a because W_C is reduced by 40.83% to 2.68% while using varies insulation materials. COPA for SAC is 5.31% to 9.84% more while using R22 refrigerant than R410a refrigerant and difference is more while using Bare pipe.

3.2 Taguchi Analysis for COP, WC

The S/N ratio and Mean are calculated for the experimental results of various tests for COP and Wc shown in table 2 and 3 respectively.

Table 2: Signal to Noise Ratio and Mean for COP

Exp No.	Insulation	Refrigerant	COP-1	COP-2	COP-3	COP-4	COP-5	SNRA 1	Mean 1
1	I1	R22	1.54	1.62	1.55	1.61	1.59	3.978813	1.582
2	I1	R410A	1.41	1.43	1.44	1.42	1.41	3.057119	1.422
3	I2	R22	2.19	2.11	2.12	2.19	2.21	6.700477	2.164
4	I2	R410A	2.03	2.03	2.05	2.02	2.05	6.175103	2.036
5	I3	R22	2.46	2.47	2.45	2.51	2.5	7.880892	2.478
6	I3	R410A	2.31	2.32	2.35	2.36	2.31	7.346067	2.33
7	I4	R22	1.97	1.93	1.94	1.96	1.96	5.808855	1.952
8	I4	R410A	1.8	1.79	1.81	1.78	1.83	5.113914	1.802
9	I5	R22	1.83	1.85	1.83	1.87	1.9	5.368924	1.856
10	I5	R410A	1.72	1.76	1.75	1.79	1.72	4.847881	1.748
11	I6	R22	1.61	1.63	1.61	1.62	1.64	4.200346	1.622
12	I6	R410A	1.47	1.46	1.47	1.45	1.44	3.274314	1.458
13	I7	R22	2.41	2.4	2.42	2.41	2.44	7.66153	2.416
14	I7	R410A	2.28	2.26	2.25	2.3	2.29	7.142578	2.276
15	I8	R22	2.52	2.53	2.53	2.54	2.56	8.082614	2.536
16	I8	R410A	2.41	2.43	2.46	2.39	2.3	7.590153	2.398

Table 3: Signal to Noise Ratio and Mean for W_c

Exp No	Insulation	Refrigerant	WC-1	WC-2	WC-3	WC-4	WC-5	SNRA1	Mean 1
1	I1	R22	2.82	2.85	2.79	2.8	2.81	-8.98671	2.814
2	I1	R410A	3.69	3.67	3.71	3.69	3.72	-11.3547	3.696
3	I2	R22	2.21	2.19	2.21	2.22	2.24	-6.90379	2.214
4	I2	R410A	2.62	2.59	2.65	2.59	2.62	-8.34643	2.614
5	I3	R22	1.89	1.93	1.93	1.96	1.97	-5.73902	1.936
6	I3	R410A	2.21	2.29	2.25	2.26	2.25	-7.05193	2.252
7	I4	R22	2.42	2.47	2.49	2.44	2.46	-7.80499	2.456
8	I4	R410A	2.89	2.92	2.95	2.91	2.92	-9.3019	2.918
9	I5	R22	2.52	2.59	2.59	2.6	2.58	-8.21946	2.576
10	I5	R410A	3	3.1	2.9	3	3	-9.54435	3
11	I6	R22	2.92	2.95	2.96	3.01	2.99	-9.44391	2.966
12	I6	R410A	3.59	3.62	3.6	3.61	3.59	-11.1309	3.602
13	I7	R22	1.92	1.98	1.99	2.01	1.98	-5.91674	1.976
14	I7	R410A	2.28	2.29	2.32	2.31	2.31	-7.24228	2.302
15	I8	R22	1.86	1.87	1.87	1.87	1.85	-5.409	1.864
16	I8	R410A	2.2	2.19	2.19	2.2	2.16	-6.80114	2.188

Analysis of the influence of INSULATION (X) and REFRIGERANT (Y) control factors on the responses are obtained from the response tables of mean S/N ratio and also the results are listed in table 4 and 5 respectively.

Table 4: Response Table for Signal to Noise Ratios for COP Larger is Better

Level	Insulation(X)	Refrigerant(Y)
1	3.518	6.210
2	6.438	5.568
3	7.613	
4	5.461	
5	5.108	
6	3.737	
7	7.402	
8	7.836	
Delta	4.318	0.642
Rank	1	2

Table 5: Response Table for Signal to Noise Ratios for WC Smaller is Better

Level	Insulation	Refrigerant
1	-10.171	-7.303
2	-7.625	-8.847
3	-6.395	
4	-8.553	
5	-8.882	
6	-10.287	
7	-6.580	
8	-6.105	
Delta	4.182	1.544
Rank	1	2

The main effect plots for S/N ratio are shown in Figure 3 and Figure 4 respectively. A larger value of S/N ratios corresponds to better quality, so optimal combination of design parameters can be obtained as X_8Y_1 for COP. A smaller value of S/N ratios corresponds to better quality, so optimal combination of design parameters can be obtained as X_8Y_1 for

W_c.

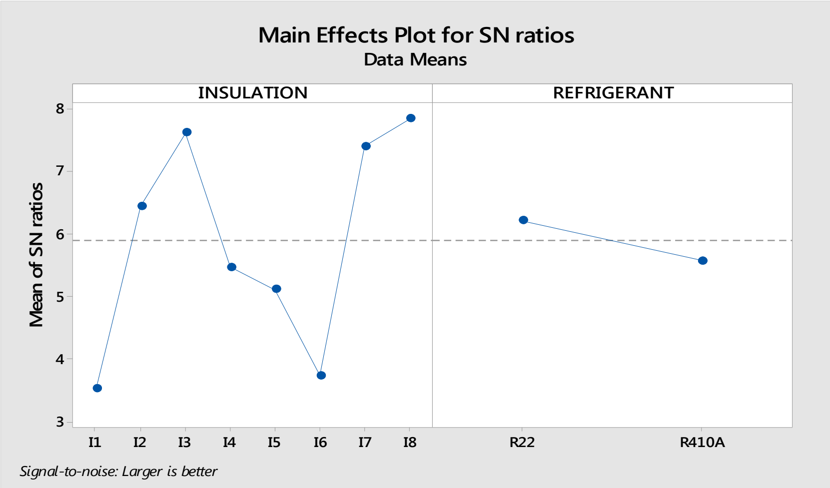

Figure 3: Main Effects Plot of S/N Ratio for COP

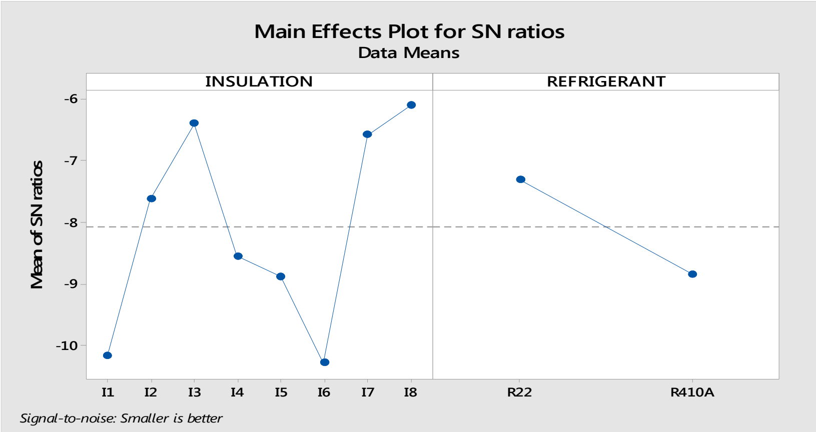

Figure 4: Main Effects Plot of S/N Ratio for W_c

With the use of Minitab software, we obtained different combinations with different insulation materials as well as Refrigerants. The software itself provided us different graphs based on the data and it will be very helpful to understand the combination which is affecting the C. O. P and W_c of the system.

The graph shows the main effects plot for S/N Ratio of performance for Vapor Compression Refrigeration Cycle corresponding to the change in the input parameters i. e. Insulation (X) and Refrigerant (Y). The X-axis is represented by the change in refrigerant and change in Insulation material and Y-axis is represented by the change in the S/N Ratio. In the above graph various insulations are I1 [BP], I2 [EPF], I3 [NRF], I4 [PFS], I5 [PFS+NYR], I6 [NYR], I7 [NRF+NYR], I8 [NRF+AF]. From the graph, it is clear that the S/N Ratio value is higher for I8 and R22 combination i. e. X_8Y_1 ie NRF+AF with R22 combination.

3.3 Analysis of Variance

The influences of the input parameters i. e. refrigerant, and insulation material on the performance of VCRS were calculated by using ANOVA. In this, the main effects plot for mean value and S/N ratio value were found/developed and analyzed. The purpose of the analysis of variance (ANOVA) and significant factors was to identify the optimal solution of the performance of the vapor compression refrigeration cycle. I used software MINITAB 18 to find the S/N ratio and plots

for the mean and S/N ratio. The study investigated the performance of VCR System using chlorodifluoromethane and a blend of difluoromethane & pentafluoroethane as the working fluids. Two parameters were examined and these are refrigerants, and insulation materials. The obtained result showed that the level of refrigerant has a significant effect on the system performance as the refrigerant changes level one to level two then the coefficient of the performance of vapor compression refrigeration system is increasing with respect to other parameters. The refrigerant is the significant parameters in influencing the performance of the vapor compression refrigeration cycle after ANOVA and S/N ratio. The temperature variation has a non-significant effect on the system performance.

From the data obtained from MiniTab18, it is clear that Insulation Material variation is affecting the Performance of the Vapour Compression Refrigeration System. From the CONTRIBUTION table, we can say that Refrigerant change is affecting 4% when changing from R410a to R22. i. e., Refrigerant R22 has Higher COP than R410a of about 4%. But, Insulation Material is affecting 96.39% when changing from one material to another i. e, while changing various Insulation Materials, NITRILE RUBBER WITH ALUMINIUM FOIL has Higher COP when compared with Bare tube, Expanded Polyethylene, Nitrile Rubber, Polyethylene Foam sheet, Polyethylene Foam sheet with Nylon Ribbon, Nylon Ribbon, and Nitrile rubber with Nylon Ribbon.

From the Results obtained, we can conclude that Refrigerant chlorodifluoromethane and Insulation Material NITRILE RUBBER WITH ALUMINIUM FOIL is the Best combination with Higher COP and also Economical. Refrigerant Blendis also affecting the Performance of the Vapour Compression Refrigeration System but the advantage with this refrigerant is it is an Eco- Friendly Refrigerant which has low ODP & GWP values. A refrigerant blend is the most balanced solution, not depleting the Ozone layer, smaller global warming compared to chlorodifluoromethane. The global warming effect is 61.7% less with compare to CHCLF2. So finally, both from Experimentation & Optimization methods, Refrigerant Blend with NITRILE RUBBER WITH ALUMINIUM FOIL will be the better combination satisfying both COP and Low ODP&GWP

Table 6: COP - ANOVA Table

Source	DF	SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
INSULATION	7	40.8006	95.85%	40.8006	5.82866	341.53	0.000000025*
REFRIGERANT	1	1.6482	3.87%	1.6482	1.64822	96.58	0.000023993*
Error	7	0.1195	0.28%	0.1195	0.01707		
Total	15	42.5683	100.00%				

*** - Significant**

Table 7: Wc - ANOVA Table

Source	DF	SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
INSULATION	7	3.5417	77.58%	3.5417	0.50595	26.22	0.00016462*
REFRIGERANT	1	0.8883	19.46%	0.8883	0.88831	46.04	0.00025667*
Error	7	0.1351	2.96%	0.1351	0.01930		
Total	15	4.5650	100.00%				

*** - Significant**

The purpose of the statistical analysis of variance is to analyze which design parameter **considerably** affects the COP of the VCRS. The analysis is carried out for the level of significance of 5% (the level of confidence is 95%). Two-way ANOVA allows comparing population means when the populations are classified according to two (categorical) factors (Insulation (X), Refrigerant (Y)). Analysis of variance results is listed in table 6 and 7 respectively. From ANOVA it can be concluded that the Insulation (X) and Refrigerant (Y) both are significant for COP and Wc This

analysis is correct since corresponding p values are small and less than 0.05. From ANOVA, we calculated the percentage contribution of input parameters. For COP experiment the percentage contribution of Insulation (X) is equal to 95.85% and Refrigerant (Y) is equal to 3.87%. For W_c experiment, the percentage contribution of Insulation (X) is equal to 77.58% and Refrigerant (Y) is equal to 19.46%.

4. CONCLUSIONS

From experimentation, it is observed that COP_A for NRF+AF gives the highest value for R22. and W_C reduced maximum while using NRF+AF. It has been observed that COP_A is high while using NRF+AF for SAC with R410a and also, the power required for SAC is less while using NRF+AF for R410a. Results like this gave us difficulty in deciding the best combination of refrigerant insulation for a VCR system. Then Optimizations of COP and Wc were done with the assistance of Taguchi analysis. It can be concluded from the S/N ratio that optimal combination of design parameters are often obtained for NRF+AF insulation material with R22 refrigerant for the fabricated system. From ANOVA the type of insulation and type of refrigerant both are significant for COP and Wc. Power required for SAC is greater while using R410a than R22 as the WC for SAC is 13.72% to 24.10% more while using R410a refrigerant than R22 refrigerant. Although, it is noted that R22 has better results when compared to R410a, t in the context of ozone layer depletion R410a is preferable than R22 with NRF+AF insulation to meet the performance of R22. Future analysis can be extended with various refrigerants.

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Nomenclature

Symbol	Description
T	Temperature
s	Entropy of refrigerant
P	Pressure of refrigerant
h	Enthalpy of refrigerant
K	Thermal conductivity of insulation material,
hC	Coefficient of convective heat transfer
TR	Temperature inside room
TO	Temperature outside room
TE-LRI	Temperature of liquid refrigerant inlet to evaporator
TE-GRO	Temp of gas refrigerant outlet from evaporator
TC-GRI	Temp of gas refrigerant inlet to compressor
TC-GRO	Temp of gas refrigerant outlet from compressor
TCO-GRI	Temp of gas refrigerant inlet to condenser
TCO-LRO	Temp of liquid refrigerant outlet from condenser
TEV-LRI	Temp of liquid refrigerant inlet to expansion valve
TEV-LRO	Temp of liquid refrigerant outlet to expansion valve
h1	Enthalpy at evaporator inlet temperature
h2	Enthalpy at evaporator outlet temperature
h3	Enthalpy at compressor inlet temperature
h4	Enthalpy at compressor outlet temperature
COPT	Theoretical COP
COPA	Actual COP
COPR	Relative COP
Q	Refrigeration effect
Cp	Specific heat of refrigerant
m	Mass flow rate
WC	Compressor work
V	Velocity of air
S/N	Signal to Noise
y_i	i^{th} experiment
n	number of experiments

Abbreviations

Symbol	Description
SAC	Split air conditioner
AC	Air conditioner
ODP	Ozone Layer Depletion
GWP	Global Warming Potential
VCRS	Vapour Compression Refrigeration System
COP	Coefficient of performance
COP_A	Actual Coefficient of performance
R22	Chlorodifluoromethane
R410a	Mixture of difluoromethane and pentafluoroethane
HVAC	Heating, ventilation and air conditioning
CFC	Chloroflouro carbon
HCFC	Hydro Cholroflouro carbon
HFC	Hydro Flouro carbon
HC	Hydrocarbon
TEWI	Total equivalent warming index
NIST	National Institute of Standards and Technology
EPF	Expanded polyethylene foam
BP	Bare pipe
NRF	Nitrile rubber foam
PFS	Polyethylene foam sheet
NYR	Nylon ribbon
NRF+AF	Nitrile rubber foam with aluminium foil
NRF+NYR	Nitrile rubber foam with nylon ribbon
PFS+NYR	Polyethylene foam sheet with nylon ribbon
ASHRAE	American Society of Heating, Refrigeration and Air-conditioning Engineers
REFPROP	Reference Fluid Thermodynamic and Transport Properties